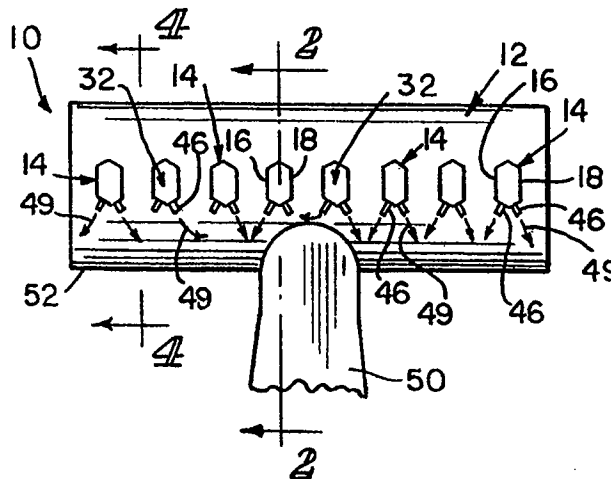




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<b>(54) Title:</b> GAS DISTRIBUTOR WITH HEADER AND SPACED APART SIDEWALLS  <b>(57) Abstract</b> <p>A gas distribution grid (613) for fluidizing material in a reaction vessel has a plurality of gas distributors (610) each having a gas inlet (50) in fluid communication with a header (12) which is in fluid communication with a plurality of arms (14) extending through header (12). Arms (14) include apertures and nozzles (46) allowing gas flowing from inlet (50) into header (12) and through arms (14) to flow through nozzles (46) into a reaction vessel to fluidize material to be contained in the reaction vessel.</p>		



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## GAS DISTRIBUTOR WITH HEADER AND SPACED APART SIDEWALLS

Background and Summary of the Invention

The present invention relates to a gas distributor. More particularly,  
5 the present invention relates to a gas distributor for use in a reaction vessel.

It is known to construct a gas distributor using components having a circular cross-section. See, for example U.S. Patent No. 5,368,824 to Nell et al. These circular conventional gas distributors are used primarily in refinery fluid catalytic cracking units and incinerators where relatively light weight materials are exposed to  
10 gases at temperatures below about 850°F (454°C).

According to the present invention, a gas distributor is provided for use in a reaction vessel. The gas distributor includes a header configured to receive heated gas having a temperature of at least 850°F (454°C) and an arm in fluid communication with the header. The arm includes generally parallel opposite side walls spaced-apart a  
15 pre-determined width. Each side wall has a top edge portion and a bottom edge portion cooperating to define a pre-determined height of the side wall. In addition, each arm has a top portion and an opposite bottom portion that extend between side walls to define a passageway therebetween. In addition, the arm is formed to include at least one aperture therethrough to permit the flow of gas out from the passageway  
20 into the reaction vessel. Further, the ratio of height to width of the arm is about 0.2:1 to about 5:1.

Preferably, the top portion of the arm includes top walls converging from the side walls to a top apex. Likewise, the bottom portion includes bottom walls converging from the side walls to a bottom apex. A plurality of spaced-apart apertures  
25 are formed through the bottom walls of the bottom portion.

Alternatively, the top portion is formed to include a generally semi-cylindrical top wall. Likewise, the bottom portion is formed to include a generally semi-cylindrical bottom wall. At least one aperture extends through the a generally semi-cylindrical bottom wall.

30 Additional features of the invention will become apparent to those skilled in the art upon consideration of the following detailed description of preferred

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embodiments exemplifying the best mode of carrying out the invention as presently perceived.

#### Brief Description of the Drawings

5                    Fig. 1 is an elevation view of a gas distributor in accordance with the present invention showing the gas distributor including an inlet duct, a distribution header coupled to the inlet duct, and hexagonally-shaped arms spaced-apart from one another and coupled to the header;

10                   Fig. 2 is a cross-sectional view taken along line 2-2 of Fig. 1 of the header showing one arm extending through the header and including a side wall including perforations therethrough to place the gas distribution header in fluid communication with the arm, a top portion extending from the side wall, and a bottom portion extending from the side wall and coupled to nozzles extending away from the side wall;

15                   Fig. 3 is a view taken along line 3-3 of Fig. 2 showing the top portion including top walls converging from the side walls to an apex and the bottom portion including bottom walls converging from the side walls to an apex;

20                   Fig. 4 is a view taken along line 4-4 of Fig. 1 showing the gas distribution header formed to include a shell that defines a passageway therethrough and spaced-apart openings extending through the shell;

                    Fig. 5 is a view similar to Fig. 2 showing an arm in accordance with the present invention extending through the gas distribution header and showing the arm including side wall, a top portion, and an opposite bottom portion formed to include an aperture sized to place the arm in communication with the gas distribution header;

25                   Fig. 6 is a view similar to Fig. 3 of an arm in accordance with the present invention showing the arm including opposing side walls, a rounded top portion extending between the side walls, and a rounded bottom portion extending between the side walls;

30                   Fig. 7 is a view similar to Fig. 3 of an arm in accordance with the present invention showing the arm including side walls spaced-apart from one another a predetermined width and being formed as an extended circle or ellipse in shape having a height greater than the predetermined width, a rounded top portion extending

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between the side walls, and a rounded bottom portion extending between the side walls;

Fig. 8 is a view similar to Fig. 3 of an arm in accordance with the present invention showing the arm including side walls spaced-apart from one another  
5 a predetermined width and being formed as an extended circle or ellipse in shape having a height greater than the predetermined width, a top portion having top walls converging from the side walls to an apex, and a bottom portion having bottom walls converging from the side walls to an apex;

Fig. 9 is a perspective view of an arm in accordance with the present  
10 invention showing the arm including spaced-apart side walls, each side wall having opposite ends and being formed to vary in height along the length of the side wall between the opposite ends, a top portion extending between the spaced-apart side walls, and an opposite bottom portion extending between the spaced-apart side walls;

Fig. 10 is a view similar to Fig. 2 showing the arm including a side wall  
15 formed to include rectangular-shaped perforations to place the gas distribution header in fluid communication with the arm, a top portion extending from the side wall, and a bottom portion extending from the side wall;

Fig. 11 is a side elevation view of a gas distributor configured for use in forming iron carbide from fluidized iron ore showing a gas inlet, a header coupled to  
20 the gas inlet and including nozzles extending from a first end of the header and from the header side walls near the first end, and arms of differing heights based upon their length coupled to the header;

Fig. 12 is a top view of the gas distributor of Fig. 11;

Fig. 13 is an end view of the first end of the header of Fig. 11;

Fig. 14 is a view taken along line 14-14 of Fig. 11 showing the shortest  
25 height of the side wall;

Fig. 15 is a view taken along line 15-15 of Fig. 11 having the second shortest height;

Fig. 16 is a view taken along line 16-16 of Fig. 11 having the second  
30 tallest height;

Fig. 17 is a view taken along line 17-17 of Fig. 11 having the tallest height; and

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Fig. 18 is a top plan view of four gas distributors of Fig. 11 formed into a gas distribution grid disposed in a cylindrical vessel to fluidize material to be contained therein.

5     Detailed Description of the Drawings

According to the present invention, a gas distributor 10 is provided that includes a gas inlet 50, a distribution header 12 coupled to the gas inlet 50, and at least one arm 14 in communication with header 12. As shown in Fig. 18, four gas distributors 10 are positioned to lie in a reaction vessel 15 to form a gas distribution grid 13. Gas distributors 10 that form gas distribution grid 13 are configured to distribute gas in a reaction vessel such as, for example, a fluidized bed reaction vessel 15. Particularly, gas distributor 10 of the present invention is capable of delivering heated gas into a bed of solids to fluidize the solids by the heated gas. While illustrated reaction vessel 15 is cylindrical and illustrated gas distribution grid 13 is formed from a combination of four gas distributors 10, it will be appreciated that reaction vessel 15 may be of any appropriate shape and that gas distribution grid 13 may be formed from a single or a plurality of gas distributors 10 configured to distribute gas in the reaction vessel.

Gas distributor 10 has a greater strength than conventional circular gas distributors and is able to conduct heated gases having a temperature that is greater than about 850°F (454°C). It is contemplated that distributor 10 may be used to supply heated gas having temperatures as high as about 1500°F (815°C) into reaction vessels 15 for the conversion of iron ore to iron carbide. It will be appreciated, however, that gas distributor 10 may be used to supply gas for a wide variety of chemical reactions or in a variety of applications such as oil refinery fluid catalytic cracking units and incinerators, or in an application where it is necessary to distribute gases through a load-bearing element. Gas distributor 10 is constructed of stainless steel, although gas distributor 10 may be constructed from any number of materials commonly used in the manufacture of vessels capable of withstanding temperatures greater than about 850°F (454°C) in accordance with the present disclosure. Some applications would include erosion resistant refractory coatings made with various ceramics including, but not limited to, oxides of aluminum and silicon, such as Resco

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AA-22, applied to the high erosion surfaces of this type of grid as erosion may be a significant failure mode in some fluidized bed grids.

Gas inlet 50 of gas distributor 10 channels heated gas to gas distribution header 12. Inlet 50 extends through reaction vessel 15 as shown by phantom lines 17 in Fig. 18. Header 12 is coupled to inlet 50 and positioned to lie within reaction vessel 15. Referring now to Figs. 2 and 5, header 12 includes a shell 52 that defines a passageway 54 therethrough. Shell 52 includes side walls 72, 74, a top portion 76 extending between side walls 72, 74, and an opposite bottom portion 78 extending between side walls 72, 74. In addition, side walls 72, 74 of header 12 are formed to include spaced-apart openings 56, 58. As shown in Fig. 2, arm 14 extends through openings 56, 58 in header 12 and is in fluid communication with passageway 54. Illustratively, shell 52 is oval in shape. It is appreciated that shell 52 may be any number of shapes, such as for example, hexagonal or elliptical without exceeding the scope of the present invention.

Side walls 72, 74 cooperate with top and bottom portions 76, 78 to define a height  $h$  of header 12. In addition, side walls 72, 74 are spaced-apart a predetermined distance and define a width  $w$  of header 12. A desirable height to width ratio provides header 12 with desirable strength characteristics. The desirable ratio of height  $h$  to width  $w$  of header 12 is generally about 0.2:1 to about 3:1, more preferably about 0.5:1 to about 2:1. Most preferably, the ratio of height  $h$  to width  $w$  of header 12 is about 0.75:1.

As best shown in Figs. 2 and 3, arm 14 extends through openings 56, 58 in header 12. Arm 14 includes a central portion 21 positioned to lie within header 12 and opposite free portions 23, 25 coupled to central portion 21 and positioned to lie externally of header 12. Central and free portions 21, 23, 25 of arm 14 include side walls 16, 18 that are spaced apart a pre-determined width 26, a top portion 28 extending between side walls 16, 18, and a bottom portion 30 extending between side walls 16, 18. Each side wall 16, 18 has a top edge portion 20 and an opposite bottom edge portion 22 that define a pre-determined height 24. Thus, height 24 is an approximation of the height of side walls 16, 18 without consideration of height of top and bottom portions 28, 30. As shown in Fig. 3, side walls 16, 18 are generally planar and are positioned to lie generally parallel to one another.

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Referring now to Fig. 2, side wall 16 of central portion 21 is formed to include generally circular perforations 48 therethrough. Side wall 18 of central portion 21 also includes perforations (not shown) therethrough. It is appreciated that the size, shape, and number of perforations 48 may vary in accordance with the present invention. For example, Fig. 10 illustrates an arm 14 where perforations are rectangular in shape. Illustratively, perforations 48 are aligned with passageway 54 of header 12 to permit gas to flow, as shown by arrows 60, from passageway 54 in header 12 into arm 14.

Top portion 28 and bottom portion 30 of arm 14 extend between side walls 16, 18 to define a passageway 32 therebetween. Top portion 28 includes top walls 34, 36 that converge from top edge portion 20 of opposite side walls 16, 18 to a top apex 38. Likewise, bottom portion 30 includes bottom walls 40, 42 that converge from bottom edge portion 22 of opposite side walls 16, 18 to a bottom apex 44. Top and bottom portions 28, 30 of arm 14 have an included angle of about 25 degrees to about 120 degrees, more preferably about 30 degrees to about 90 degrees, and most preferably about 90 degrees.

Referring to Fig. 1, bottom portion 30 is formed to include a plurality of spaced apart apertures that receive illustrative nozzles 46. Nozzles 46 are in communication with passageway 32 of arm 14 to channel gas, as shown by arrows 49, into an environment away from gas distributor 10. Alternatively, gas distributor 10 may be formed without nozzles 46 so that gas may flow directly from arm 14 into the environment surrounding gas distributor 10. In addition, it is appreciated that the number, spacing, and positioning of nozzles may vary in accordance with the present disclosure. In fact, arm 14 may be formed to include apertures (not shown) in side walls 16, 18 or top portion 28.

Arm 14 of gas distributor 10 has a desirable height to width ratio. This height to width ratio provides arm 14 with desirable strength characteristics that are suitable for withstanding elevated temperatures. The ratio of height 24 to width 26 of arm 14 is about 0.2:1 to about 5:1, more preferably about 1:1 to about 5:1. Most preferably, the ratio of height 24 to width 26 of arm 14 is about 1.5:1.

Strength characteristics of arm 14 are measured by a centroidal moment of inertia and a section modulus of the element. Section modulus is calculated by



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dividing the moment of inertia by the distance from the center of the element to an outermost fiber of the element. When bending is the predominant loading imposed on

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the element, then the section modulus will indicate the relative strengths of the elements being compared. The bending stress  $\sigma$  (psi) is defined as:

$$\sigma = M(c) / I;$$

where M is the bending moment (in. \*lb), c is the from the center to the outermost fiber (in.), and I is the moment of inertia of the cross-section of the element in bending(in<sup>4</sup>).

COMPARISON OF CONVENTIONAL ROUND PIPE  
WITH HEX PIPE OF THE PRESENT INVENTION

10			6 in. (15 cm) round pipe XXS (double extra strong)	8 in. (20 cm) round pipe sch 160	10 in. (25 cm) round pipe sch 160	6 in. (15 cm) hex 6 in. (15 cm) planar side	6 in. (15 cm) hex 8 in. (20 cm) planar side	6 in. (15 cm) hex 10 in. (25 cm) planar side
	Projected width Plan View (in)		6.625 (16.8 cm)	8.625 (21.9 cm)	10.75 (27.3 cm)	6 (15 cm)	6 (15 cm)	6 (15 cm)
	Section Modulus, (in <sup>3</sup> )	Axis x-x	20.03 (328 cm <sup>3</sup> )	38.5 (631 cm <sup>3</sup> )	74.3 (1217 cm <sup>3</sup> )	31.29 (513 cm <sup>3</sup> )	41.06 (673 cm <sup>3</sup> )	52.25 (879 cm <sup>3</sup> )
		Axis y-y	20.03 (328 cm <sup>3</sup> )	38.5 (631 cm <sup>3</sup> )	74.3 (1217 cm <sup>3</sup> )	23.7 (388 cm <sup>3</sup> )	28.7 (470 cm <sup>3</sup> )	33.8 (554 cm <sup>3</sup> )
	Moment of Inertia, (in <sup>4</sup> )	Axis x-x	66.3 (2760 cm <sup>3</sup> )	165.9 (6905 cm <sup>3</sup> )	399 (16607 cm <sup>3</sup> )	187.7 (7812 cm <sup>3</sup> )	287.4 (11962 cm <sup>3</sup> )	418 (17397 cm <sup>3</sup> )
		Axis y-y	66.3 (2760 cm <sup>3</sup> )	165.9 (6905 cm <sup>3</sup> )	399 (16607 cm <sup>3</sup> )	71.1 (2959 cm <sup>3</sup> )	86.2 (3588 cm <sup>3</sup> )	101.4 (4220 cm <sup>3</sup> )
	Wall Thickness (in)		0.864 (2.2 cm)	0.906 (2.3 cm)	1.125 (2.86 cm)	0.5 (1.27 cm)	0.5 (1.27 cm)	0.5 (1.27 cm)
Weight per foot (lbs)		53.16 (236.6 N)	74.69 (332.4 N)	115.65 (514.6 N)	45.5 (202.5 N)	52.26 (232.6 N)	59 (262.6 N)	
Flow area, (in <sup>2</sup> )		18.83 (122 cm <sup>2</sup> )	36.5 (236 cm <sup>2</sup> )	56.7 (366 cm <sup>2</sup> )	40.35 (260 cm <sup>2</sup> )	50.35 (325 cm <sup>2</sup> )	60.35 (389 cm <sup>2</sup> )	

25

The advantages of increased moment of inertia of the cross section and section modulus become apparent when arms 14 need to become longer to span

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greater areas in the reactors 15. In those cases, the height of the side walls 16, 18 becomes taller, and the arms 14 become stronger without enlarging the plan view projected cross-section width of arm 14, as is necessary with round pipe. See, for example, Fig. 3 and the first row of the above table. The hexagonal shape of the present invention enables large numbers of nozzles 46 to be deployed in reactor 15, provides for larger gas passageways 32, and provides a built-in feature of a sharp edge 38, 44 to penetrate through the iron ore bed if necessary.

A gas distributor 110 is provided in accordance with the present invention that includes gas inlet 50, header 12 coupled to gas inlet 50, and an arm 114 coupled to header 12. As shown, for example, in Fig. 5, arm 114 of gas distributor 110 has generally the same height to width ratio as arm 14 and therefore possesses generally the same strength characteristics as arm 14. Arm 114 is formed similarly to arm 14 and like reference numerals will be used to denote like components. Arm 114 includes side walls 16, 18 and top and bottom portions 128, 130 extending between side walls 16, 18 to define a passageway 132 therebetween.

Referring now to Fig. 5, bottom portion 130 of arm 114 is formed to include slots 148 in general alignment with passageway 54 of header 12 to permit the flow of gas, as shown by arrow 160 from passageway 54 of header 12 into passageway 132 of arm 114. The size, shape, and number of slots 148 may vary in accordance with the present invention. Bottom portion 130 also includes spaced-apart apertures 99 positioned to lie externally of header 12. As shown in Fig. 5, nozzles 46 extend through the apertures 99 formed in bottom portion 130 of arm 114. Nozzles 46 are in communication with passageway 132 of arm 14 to channel gas, as shown by arrows 49, into an environment away from gas distributor 110. Gas distributor 110 may be formed without nozzles 46 as previously discussed.

Referring to Fig. 6, arm 214 is provided in accordance with the present invention to cooperate with header 12 and gas inlet 50. Arm 214 is formed similarly to arm 14 and like reference numerals will be used to denote like components. Arm 214 includes a top portion 228 and an opposite bottom portion 230 extending between side walls 16, 18 to define a passageway 232 therebetween. Top portion 228 and bottom portion 230 are generally semi-cylindrical in shape. Nozzles (not shown) extend from bottom portion 230 of arm 214 as previously discussed with reference to arm 14.

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Arm 314 is provided in accordance with the present invention to cooperate with header 12 and inlet 50. Arm 314 is illustrated in Fig. 7 and includes side walls 316, 318 that are spaced apart at their widest point of separation 360 by a pre-determined width 326 and top and bottom portions 328, 330 extending between  
5 side walls 316, 318 to define a passageway 332 therebetween. Top portion 328 and bottom portion 330 are generally semi-cylindrical in shape. Nozzles (not shown) extend from arm 214 as previously discussed with arm 14.

Side walls 316, 318 of arm 314 each include a middle portion 360 and opposite ends 320, 322. Middle portion 360 of side walls 316, 318 cooperate to  
10 define width 326. Ends 320, 322 of side walls 316, 318 cooperate to define a second pre-determined width 327. Illustratively, second pre-determined width 327 is less than first pre-determined width 326. Ends 320, 322 of each side wall 316, 318 define a pre-determined height 324. Side walls 316, 318 are formed as an extended circle, such that height 324 of side walls 316, 318 is greater than widths 326 and 327. The ratio of  
15 height 324 to width 326 of arm 314 is about 0.2:1 to about 5:1, more preferably about 1:1 to about 5:1. Most preferably, the ratio of height 324 to width 326 of arm 314 is about 1.5:1. Thus, side walls 316, 318 of arm 314 can be curved on a large radius to approximate the benefit of the generally planar side, and to achieve the desired ratio of height 324 to width 326.

20 Arm 414 is provided in accordance with the present invention to cooperate with header 12 and inlet 50. Arm 414 is illustrated in Fig. 8 and includes side walls 416, 418 that are spaced-apart from one another and top and bottom portions 428, 430 extending between side walls 416, 418 to define a passageway 432. Side walls 416, 418 each include a middle portion 460 and opposite ends 420, 422.  
25 Middle portion 460 of side walls 416, 418 cooperate to define a first pre-determined width 426. Ends 420, 422 of side walls 416, 418 cooperate to define a second pre-determined width 427. Illustratively, second pre-determined width 427 is less than first pre-determined width 426. Opposite ends 420, 422 of each side wall 416, 418 define a pre-determined height 424.

30 Side walls 416, 418 are formed as an extended circle, such that height 424 of side walls 416, 418 is greater than widths 426 and 427. See Fig. 8. The ratio of height 424 to first pre-determined width 426 of arm 414 is generally about 0.2:1 to

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about 5:1, more preferably about 1:1 to about 5:1. Most preferably, the ratio of height 424 to first pre-determined width 426 of arm 414 is about 1.5:1. Thus, side walls 416, 418 of arm 414 can be curved on a large radius to approximate the benefit of the generally planar side, and to achieve the desired ratio of height 424 to width 426.

5 In addition, top portion 428 of arm 414 includes top walls 434, 436 that converge from top edge portion 420 of opposite side walls 416, 418 to a top apex 438. Likewise, bottom portion 430 includes bottom walls 440, 442 that converge from bottom edge portion 422 of opposite side walls 416, 418 to a bottom apex 444. Top and bottom portions 428, 430 of arm 414 have an included angle of about 25 degrees  
10 to about 120 degrees, more preferably about 30 degrees to about 90 degrees, and most preferably about 90 degrees. Nozzles (not shown) extend from arm 414 as previously discussed with arm 14.

Arm 514 is provided in accordance with the present invention to cooperate with header 12 and inlet 50. Arm 514 is illustrated in Fig. 9 and is formed  
15 similarly as arm 14 and like reference numerals will be used to denote like components. Arm 514 includes side walls 516, 518 that are spaced apart a pre-determined width 26 and top and bottom portions 528, 530 extending between side walls 516, 518 to define a passageway 532. Each side wall 516, 518 has a top edge portion 520 and an opposite bottom edge portion 522. Side walls 516, 518 of arm 514 also include  
20 opposite ends 570, 572 spaced apart a pre-determined length and a middle portion 574 therebetween. Side walls 516, 518 are generally planar and are positioned to lie generally parallel to one another.

As shown in Fig. 9, top and bottom edge portions 520, 522 of the opposite ends 570, 572 have a first pre-determined height 524 and the middle portion  
25 574 has a second pre-determined height 525. Thus, the height of the side walls 516, 518 varies along its length. In particular, top edge portion 520 diverges from opposite ends 570, 572 toward middle portion 574. Thus, the height of side walls 516, 518 increases from height 524 toward height 525 at middle portion 574. Arm 514, therefore, uses a reduced amount of material to construct. The ratio of height 524 to  
30 width 26 of arm 514 is generally about 0.2:1 to about 5:1, more preferably about 1:1 to about 5:1. Most preferably, the ratio of height 524 to width 26 of arm 514 is about 1.5:1. Thus, side walls 516, 518 of arm 514 can be curved on a large radius to

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approximate the benefit of the generally planar side, and to achieve the desired ratio of height 524 to width 26.

Top portion 528 of arm 514 also includes top walls 534, 536 that converge from top edge portion 520 of opposite side walls 516, 518 to a top apex 538. Likewise, bottom portion 530 includes bottom walls 540, 542 that converge from bottom edge portion 522 of opposite side walls 516, 518 to a bottom apex 544. Top and bottom portions 528, 530 of arm 514 have an included angle of about 25 degrees to about 120 degrees, more preferably about 30 degrees to about 90 degrees, and most preferably about 90 degrees. Nozzles (not shown) extend from arm 514 as previously discussed with arm 14.

Each of the arm embodiments 14, 114, 214, 314, 414, 514 may be combined with header 12 and gas inlet 50 to define a gas distribution grid 13 which is inserted into a vessel or chamber 15 containing a bed of material to be fluidized. While the following refers only to arms 14, it is to be appreciated that such discussion is equally applicable to arm embodiments 114, 214, 314, 414, 514. It is also to be appreciated that a single gas distribution grid 13 may be formed from a plurality of arms of the various embodiments with each arm having a different length to provide substantially uniform gas distribution to the vessel 15. Fluidization of the material may be the desired end or may be a step in furthering a process such as fluid catalytic cracking or formation of iron carbide from iron ore. The dimensions (thickness, height, width, and length) of the arms 14, header 12, and inlet 50, as well as the choice of material forming the side walls and top and bottom surfaces of arms 14 and header 12, depends upon the specific application to which the gas distributor 10 is to be put.

Among the variables considered in selecting the material for, and the dimensions of, the gas inlet 50, header 12 and arms 14 are: the vessel or chamber size; the required amount of fluidization gas; the temperature, pressure and mole weight of fluidization gas; and the rough size of the flow conduits (based on arm count and size and length of the arms 14) required to evenly distribute gas to all of the zones of the bed. Vessel or chamber size is typically dictated by the specific requirements of the application. Once the vessel size has been selected, the remaining variables may be determined.

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Determination of the required amount of fluidization gas will be based on the bed height, the density of the solids in the bed, the process chemistry, and other bed fluidization characteristics. Gas distribution grids 10 are generally supported by inlet flow conduits 50 or pipe ducts that supply gas to grids 10. Grids 10 are generally supported by vertical inlet duct pipes 50 penetrating through the bottom of vessel 15. A presently preferred procedure for determination of the required amount of fluidization gas is to rough size inlet 50, header 12 and arms 14 based on mechanical strength requirements for supporting an unfluidized bed and then, using an actual flow velocity criteria such as 3000 fpm, check for pressure drop resulting from fluidization. Based on the determined pressure drop in the first design iteration, the sizes of inlet 50, header 12, and arms 14 are appropriately adjusted in future iterations to achieve acceptable maximum pressure drops through arms 14 and header 12.

The described gas distributor 10 is constructed of stainless steel, however, it is appreciated that gas distributor 10 may be constructed from other materials. The material from which inlet 50, header 12, and arms 14 of gas distributor 10 are formed is selected based on process chemistry considerations (i.e., corrosion, various types of metallurgical attack, creep strength at temperature) for the specific application to which gas distributor 10 is to be put.

The mechanical strength requirements of inlet 50, header 12, and arms 14 depends on the allowable stress at the desired operating temperature considering bed loading (both static and dynamic) on grids 13. The presently preferred basis for determining bed load on grid 13 depends on the bed weight which supplies a vertical load on the components and dynamic bed action or fluidization which supplies a horizontal load on the components having a magnitude possibly as great as 30 % of the bed weight. Arms 14 and headers 12 are considered to be beams bending from uniform loading, either horizontal or vertical.

In the first iteration of the design, the material thickness of arms 14 and headers 12 are chosen and moments of inertia are calculated to allow stresses to be checked. The material thickness of arms 14 and headers 12 is calculated to accommodate maximum allowable stresses at temperature (creep strength). Once the material thickness is initially calculated to accommodate external loads, new moments of inertia are calculated based on material thickness and stresses on the components

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are rechecked to ensure they are within acceptable ranges. If the stresses are not within acceptable ranges, header 12 and/or arm 14 heights may need to be extended to achieve higher moments of inertia and lower stresses.

In subsequent iterations thicknesses and sizes are changed until  
5 acceptable stresses are achieved. Generally longer arms 14 require taller section heights because of the higher moment loading. Also the stress on vertical inlet duct 50 due to bending moment induced by header/arms complex and direct compression loading is calculated to ensure that such stresses are within desired limits. If the stresses on vertical inlet duct 50 are not within acceptable limits, the thickness or  
10 diameter of inlet duct 50 is adjusted as required.

In addition to, or as an alternative to, adjusting the height or thickness of arm 14 or header 12, reinforcing pads 19 can be added to arm 14 or header 12 to accommodate high stress points, as shown, for example in Figs. 11, 12, 16, 17. In the illustrated embodiment, reinforcing pads 19 are made from half inch (1.2 cm) stainless  
15 steel plates, and are attached to arm 14 or header 12 with a weld 29, as shown for example in Figs. 16, 17. It is appreciated that reinforcing pad 19 may be constructed from other materials, and may be attached to header 14 by other methods. The material from which reinforcing pad 19 is formed, and the manner of attachment of reinforcing pad 19, are selected based on process chemistry considerations (i.e.,  
20 corrosion, various types of metallurgical attack, creep strength at temperature) for the specific application to which gas distributor 10 is to be put.

Once the dimensions of inlet 50, header 12, and arms 14 have been adjusted to allow for proper fluidization gas flow and to withstand the stresses of being submerged in the bed material during fluidization, the natural frequency of arms 14  
25 should be checked to ensure no component of the system as designed has a natural frequency of less than 20 HZ. The longest arm 14 generally has the lowest natural frequency. If the natural frequency of arm 14 is lower than 20 HZ, the stiffness of arm 14 should be increased by adding reinforcement pads to sides or top of arm 14 to increase its section modulus. Each arm 14 will have different natural frequencies in  
30 each axis and generally the horizontal bending direction, about the y-axis, will produce the lowest natural frequency.



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The preferred method of determining the natural frequency of arm 14 uses the formula:

$$F_n = .56 ( (g * E * I) / (w * L^4) )^{0.5}$$

where,  $F_n$  is the natural frequency (Hz),  $I$  is the centroidal moment of inertia about axis of bending ( $\text{in}^4$ ),  $g$  is the gravitational constant ( $\text{in./sec}^2$ ),  $E$  is the elastic modulus (psi),  $w$  is the beam weight (lb/in. length), and  $L$  is the length of beam (in.).

Gas distributors 10 designed in accordance with the forgoing may be incorporated into vessels designed to contain bed of material to be fluidized and may operate in harsher conditions than gas distributors containing tubular arms. Referring to Figs. 11 - 18, a gas distribution grid 613, including four gas distributors 610, for use in a reaction vessel containing iron ore to be formed into iron carbide designed using the above disclosed parameters is illustrated. Each gas distributor 610 includes a header 612, a gas inlet 650, and a plurality of arms 614a, 614b, 614c, 614d, 614e, 614f, 614g forming a gas distribution grid 613 as shown in Fig. 18.

Referring to Figs. 11-13, header 612 has a height  $h$  of 20 in. (50 cm) and a width  $w$  of 24 in. (60 cm) and includes top and bottom edge portions 676, 678 which are semi-cylindrical having a radius of 12 inches (30 cm). Header 612 is 8 ft. 10.75 in. (2.7 m) long and has a first end wall 679 and a spaced-apart second end wall 681 enclosing both ends of passageway 654. First end wall 679 and the portion of side walls 672 and 674 within approximately 5 in. (12 cm) of first end wall 679 are formed to include apertures 683 communicating between passageway 654 and the surrounding environment. Apertures 683 receive illustrative nozzles 647 in communication with passage way 654 to channel gas, into an environment away from the gas distributor 610. In the illustrated gas distributor, twenty (20) nozzles 647 are incorporated into header 612 with fourteen (14) of those nozzles being incorporated into the first end wall 679 and three (3) nozzles each being incorporated into side walls 672 and 674 as shown for example in Figs. 11 -13.

Arms 614a-g are all of the type of the first embodiment of arm 14 as described previously, but have varying heights 624a-g and lengths 639a-g. Each arm 614a-g is formed from 0.5 in. (1.2 cm) bent plate and has a generally hexagonal cross-section with nozzles 646 extending from opposite bottom walls 640, 642. Each nozzle 646 is spaced apart from the next nearest nozzle 646 on the same bottom wall

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by a displacement 690 of 1 5/8 in. (4.1 cm). Each arm 614a-g also includes a first end wall 631 and a spaced apart second end wall 633 enclosing passage 632. Arms 614a-g extend through header 612 so that free portions 623, 625 are of equal length with central portion 621 extending therebetween as shown, for example, on arm 614g in

5 Fig. 12.

As shown, for example, in Fig. 12, arm 614a has a total length 639a of 4 foot 6.75 in. (1.4 m) and includes thirty-two (32) nozzles 646 with sixteen (16) nozzles protruding from bottom wall 640 and sixteen (16) nozzles 646 protruding from bottom wall 642. In all of the arms 614a-g, nozzles 646 are equally distributed  
10 between free ends 623, 625 and also between bottom walls 640, 642. The first of the sixteen (16) nozzles on each bottom wall 640, 642 of arm 614a is displaced from the nearest side wall 672, 674 of header 612 by a displacement of 2 in. (5 cm). As shown, for example, in Fig. 14, arm 614a has a height 624a of 6 in. (15 cm) and a width 626 of 6 in. (15 cm).

15 As shown, for example, in Fig. 12, arm 614b has a total length 639b of 6 foot 11 in. (2.1 m) and includes sixty-four (64) nozzles 646 with thirty-two (32) nozzles protruding from bottom wall 640 and thirty-two (32) nozzles 646 protruding from bottom side 642. The first of the thirty-two (32) nozzles on each bottom wall 640, 642 of arm 614b is displaced from the nearest side wall 672, 674 of header 612 by  
20 a displacement of 2 13/16 in. (7 cm). As shown, for example, in Fig. 14, arm 614b has a height 624b of 6 in. (15 cm) and a width 626 of 6 in. (15 cm).

As shown, for example, in Fig. 12, arm 614c has a total length 639c of 9 foot 3.25 in. (2.8 m) and includes one hundred (100) nozzles 646 with fifty (50) nozzles protruding from bottom wall 640 and fifty (50) nozzles 646 protruding from  
25 bottom side 642. The first of the fifty (50) nozzles on each bottom wall 640, 642 of arm 614c is displaced from the nearest side wall 672, 674 of header 612 by a displacement of 2 in (5 cm). As shown, for example, in Fig. 15, arm 614c has a height 624c of 8 in. (20 cm) and a width 626 of 6 in. (15 cm).

As shown, for example, in Fig. 12, arm 614d has a total length 639d of  
30 12 foot 7 in. (3.8 m) and includes one hundred forty-eight (148) nozzles 646 with seventy-four (74) nozzles 646 protruding from bottom wall 640 and seventy-four (74) nozzles 646 protruding from bottom side 642. The first of the seventy-four (74)

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nozzles on each bottom wall 640, 642 of arm 614d is displaced from the nearest side wall 672, 674 of header 612 by a displacement of  $2 \frac{13}{16}$  in. (7 cm). As shown, for example, in Fig. 16, arm 614d has a height 624d of 10 in. (25 cm) and a width 626 of 6 in. (15 cm).

5 Referring again to Fig. 12, arm 614e has a total length 639e of 14 foot 6 in (4.4 m) and includes one hundred seventy-six (176) nozzles 646 with eighty-eight (88) nozzles 646 protruding from bottom wall 640 and eighty-eight (88) nozzles 646 protruding from bottom side 642. The first of the eighty-eight (88) nozzles on each bottom wall 640, 642 of arm 614e is displaced from the nearest side wall 672, 674 of header 612 by a displacement of 2 in. (5 cm). As shown, for example, in Fig. 17, arm 614e has a height 624e of 12 in. (0.3 m) and a width 626 of 6 in. (15 cm).

As shown, for example, in Fig. 12, arm 614f has a total length 639f of 12 foot 3.75 in. (3.7 m) and includes one hundred forty-four (144) nozzles 646 with seventy-two (72) nozzles 646 protruding from bottom wall 640 and seventy-two (72) nozzles 646 protruding from bottom side 642. The first of the seventy-two (72) nozzles on each 2 bottom wall 640, 642 of arm 614f is displaced from the nearest side wall 672, 674 of header 612 by a displacement of  $2 \frac{13}{16}$  in. (7 cm). As shown, for example, in Fig. 16, arm 614f has a height 624f of 10 in. (25 cm) and a width 626 of 6 in. (15 cm).

20 As shown, for example, in Fig. 12, arm 614g has a total length 639g of 6 foot 8 in. (2 m) and includes sixty (60) nozzles 646 with thirty (30) nozzles protruding from bottom wall 640 and thirty (30) nozzles 646 protruding from bottom side 642. The first of the thirty (30) nozzles on each bottom wall 640, 642 of arm 614g is displaced from the nearest side wall 672, 674 of header 612 by a displacement of 2 in. (5 cm). As shown, for example, in Fig. 14, arm 614g has a height 624g of 6 in. (15 cm) and a width 626 of 6 in. (15 cm).

As shown, for example, in Fig. 11, nozzles 646 and 647 are at the same vertical position relative to side walls 672, 674. Thus gas distributor 610 fluidizing gas to a bed of material in a substantially uniform manner.

30 Although the invention has been described with reference to certain embodiments, variations exist within the scope and spirit of the invention as described and defined in the following claims.

## WHAT IS CLAIMED IS:

1. A gas distributor comprising:  
an arm configured to receive heated gas having a temperature of at least 850°F (454°C), the arm including side walls spaced-apart a predetermined width, a top  
5 portion extending between the side walls, and a bottom portion extending between the side walls and formed to include at least one aperture, the side walls each having a top edge portion and an opposite bottom edge portion cooperating to define a pre-determined height and the ratio of height to width of the side walls is about 0.2:1 to about 5:1.
- 10 2. The gas distributor of claim 1, wherein the ratio of height to width of the side walls is about 1:1 to about 5:1.
3. The gas distributor of claim 2, wherein the ratio of height to width of the side walls is about 1.5:1.
4. The gas distributor of claim 1, wherein the top portion includes  
15 top walls converging from the side walls to a top apex.
5. The gas distributor of claim 4, wherein the side wall of the arm is formed to include a plurality of apertures therethrough.
6. The gas distributor of claim 4, wherein the bottom portion includes bottom walls converging from the side walls to a bottom apex.
- 20 7. The gas distributor of claim 1, wherein the top portion includes a generally semi-cylindrical top wall.
8. The gas distributor of claim 7, wherein the bottom portion includes a generally semi-cylindrical bottom wall.
9. The gas distributor of claim 7, wherein the arm is generally  
25 elliptical in shape.
10. A gas distributor comprising:  
a header being configured to receive heated gas having a temperature of at least 850°F (454°C),  
an arm in fluid communication with the header, the arm including side  
30 walls spaced-apart a predetermined width, a top portion extending between the side walls, and a bottom portion extending between the side walls and formed to include at least one aperture, the side walls each having a top edge portion and an opposite

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bottom edge portion cooperating to define a pre-determined height and the ratio of height to width of the side walls is about 0.2:1 to about 5:1.

11. The gas distributor of claim 10, wherein the header includes a shell having spaced-apart side walls that define a passageway and at least one of the side walls is formed to include at least one opening.

12. The gas distributor of claim 11, wherein at least one of the side walls of the arm includes at least one aperture in general alignment with the at least one opening of the shell.

13. The gas distributor of claim 11, wherein the bottom portion of the arm includes at least one aperture in general alignment with the at least one opening of the shell.

14. The gas distributor of claim 10, wherein the ratio of height to width of the side walls is about 1:1 to about 5:1.

15. The gas distributor of claim 14, wherein the ratio of height to width of the side walls is about 1.5:1.

16. The gas distributor of claim 14, wherein the arm is generally hexagonal in shape.

17. The gas distributor of claim 16, wherein the top portion includes top walls converging from the side walls to a top apex.

18. The gas distributor of claim 14, wherein the arm is generally elliptical in shape.

19. A gas distributor comprising:

a header configured to receive heated gas having a temperature of at least 850°F (454°C), the header including a shell having spaced-apart side walls that define a passageway and the side walls being formed to include an aperture,

an arm extending through the aperture of the shell, the arm including side walls spaced-apart a pre-determined width and top and bottom portions extending between side walls to define a passageway, the side walls each being formed to include a top edge portion, an opposite bottom edge portion cooperating with the top edge portion to define a pre-determined height, and perforations being aligned with the passageway of the header to receive the heated gas, and the ratio of height to width of the arm is about 0.2:1 to about 5:1.

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20. The gas distributor of claim 19, wherein the header includes opposite side walls spaced-apart a pre-determined width, each side wall having a top edge portion and an opposite bottom edge portion cooperating to define a pre-determined height, a top portion and an opposite bottom portion extending between  
5 side walls to define the passageway therebetween.

21. The gas distributor of claim 20, wherein the ratio of the height to width of the header is about 0.2:1 to about 3:1.

22. The gas distributor of claim 21, wherein the ratio of the height to width of the header is about 0.5:1 to about 2:1.

10 23. The gas distributor of claim 22, wherein the ratio of the height to width of the header is about 0.75:1.

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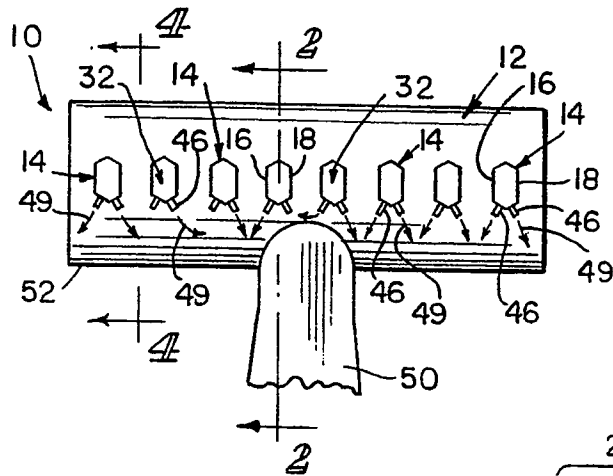


FIG. 1

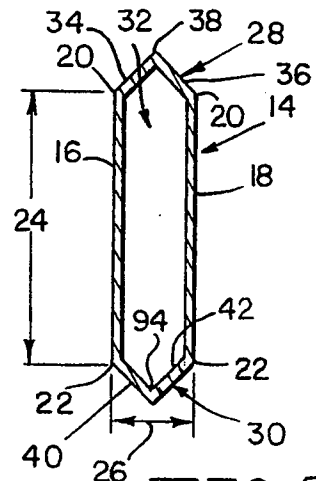


FIG. 3

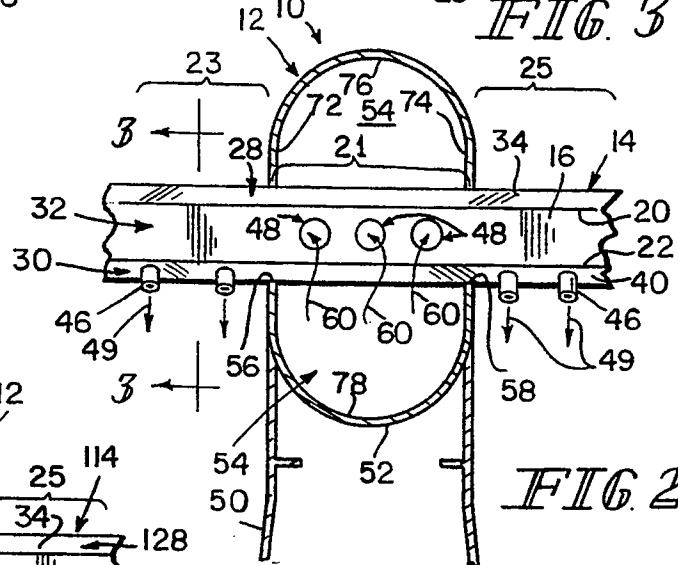


FIG. 2

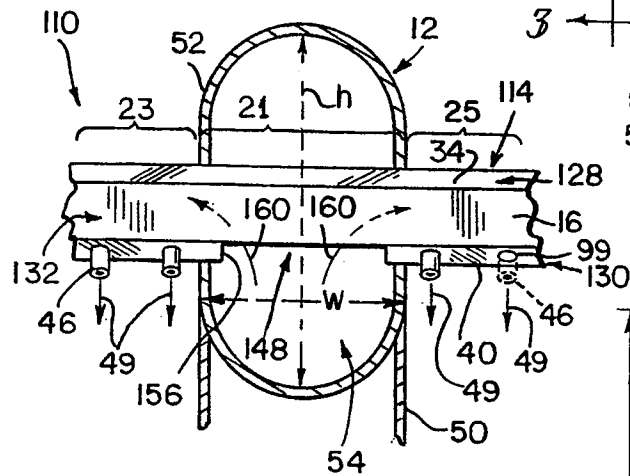


FIG. 5

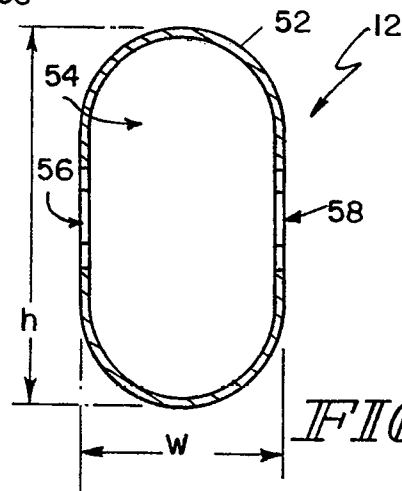


FIG. 4

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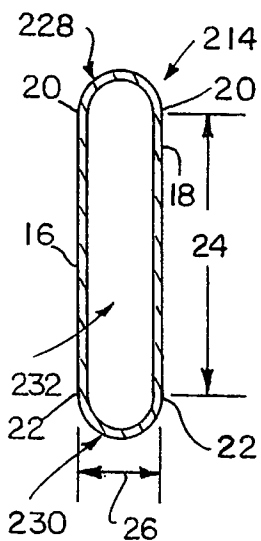


FIG. 6

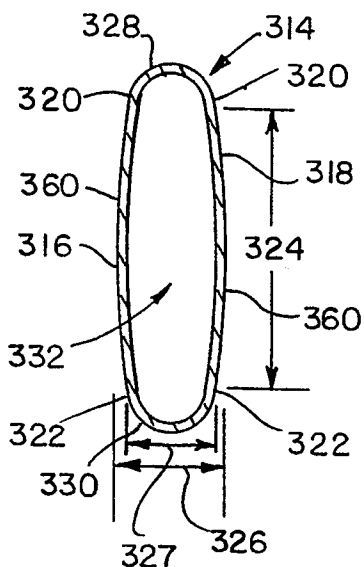


FIG. 7

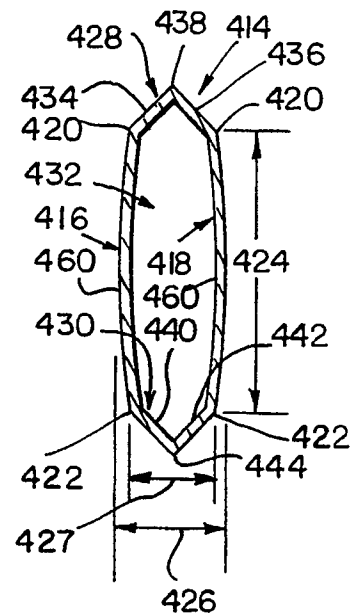


FIG. 8

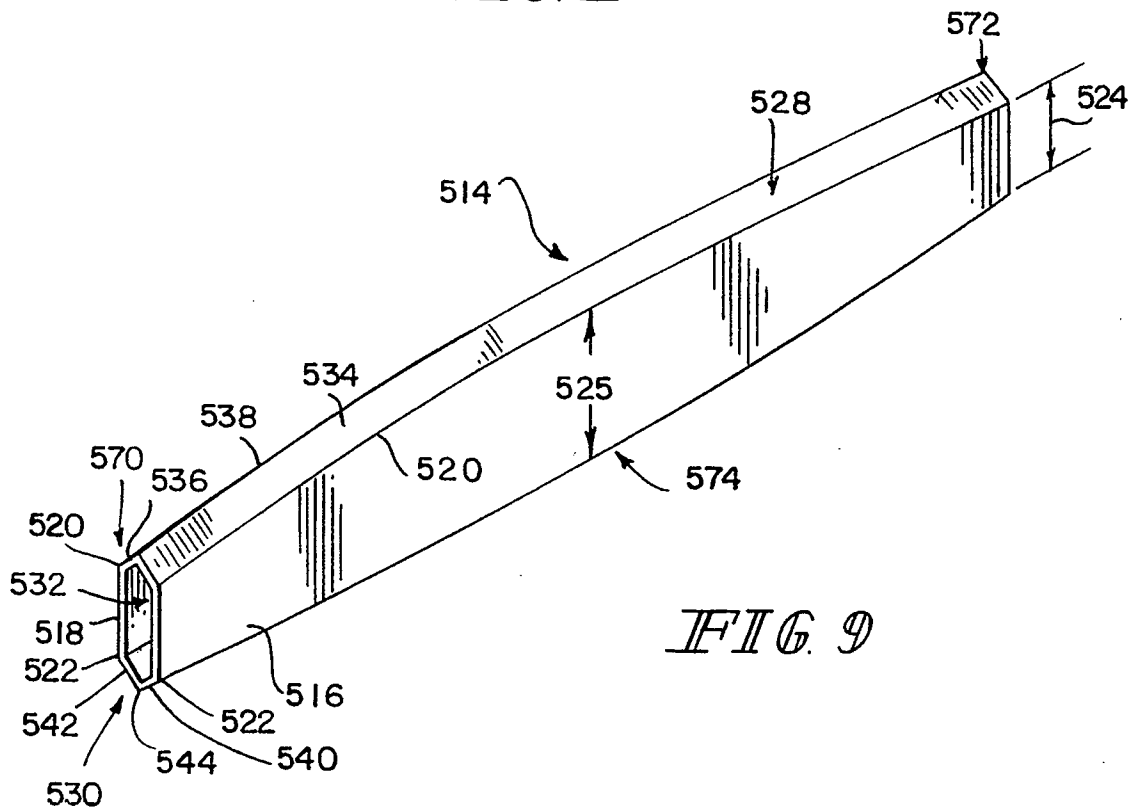


FIG. 9



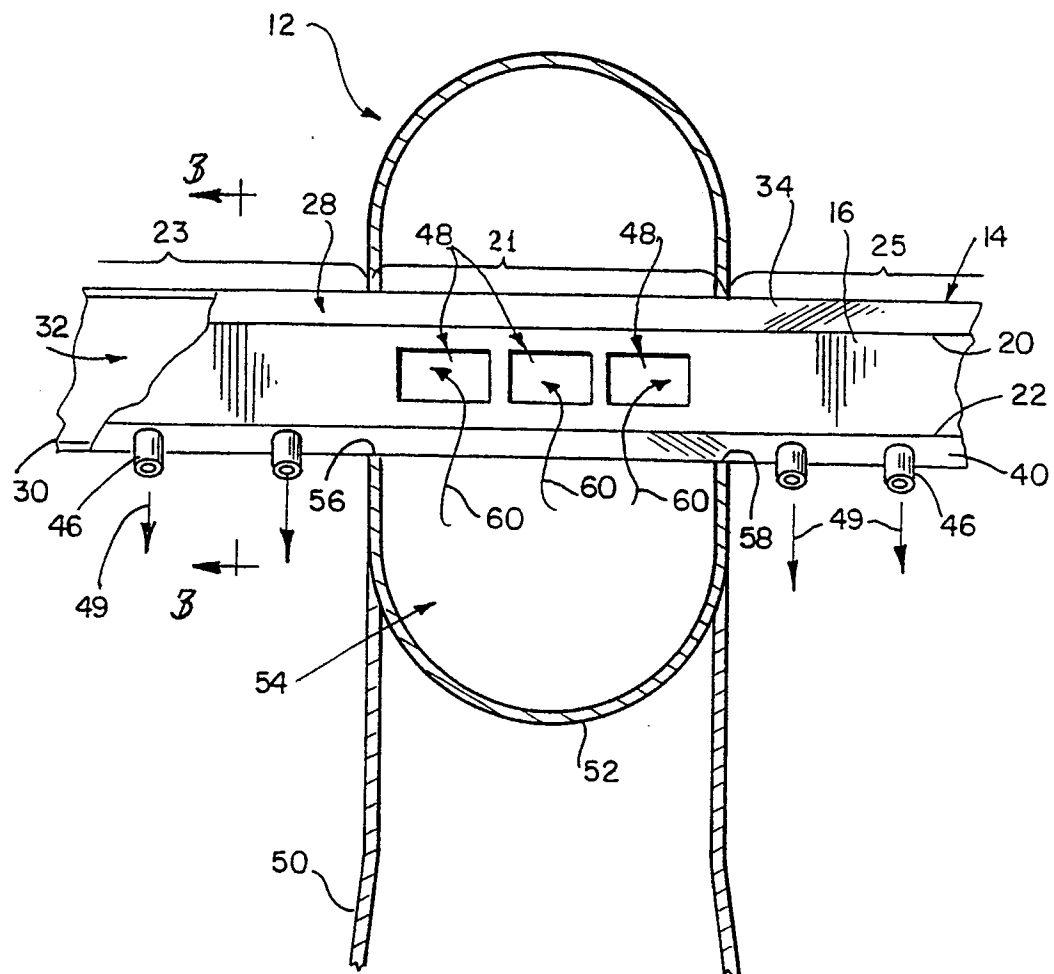
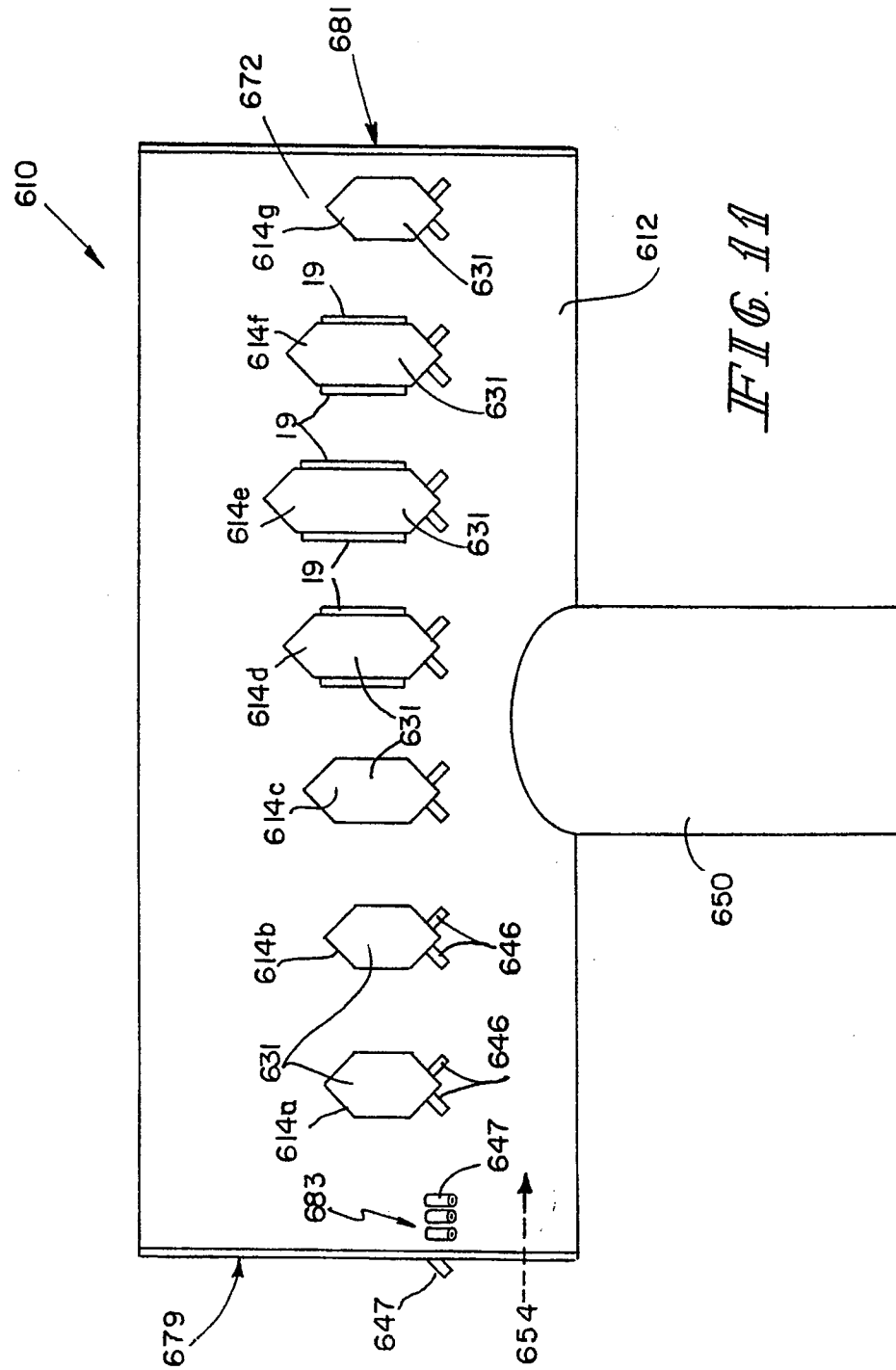


FIG 10



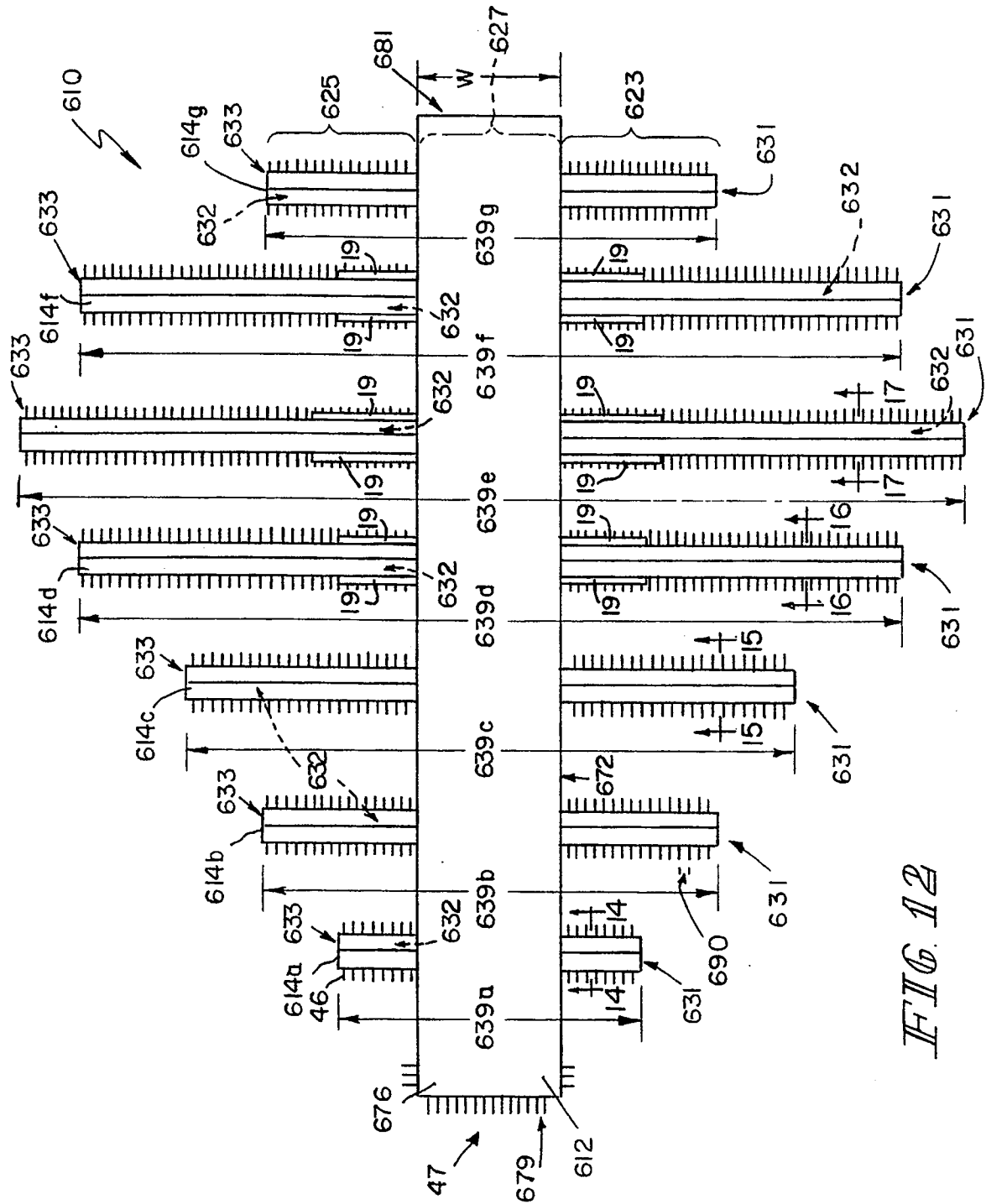


FIG. 12

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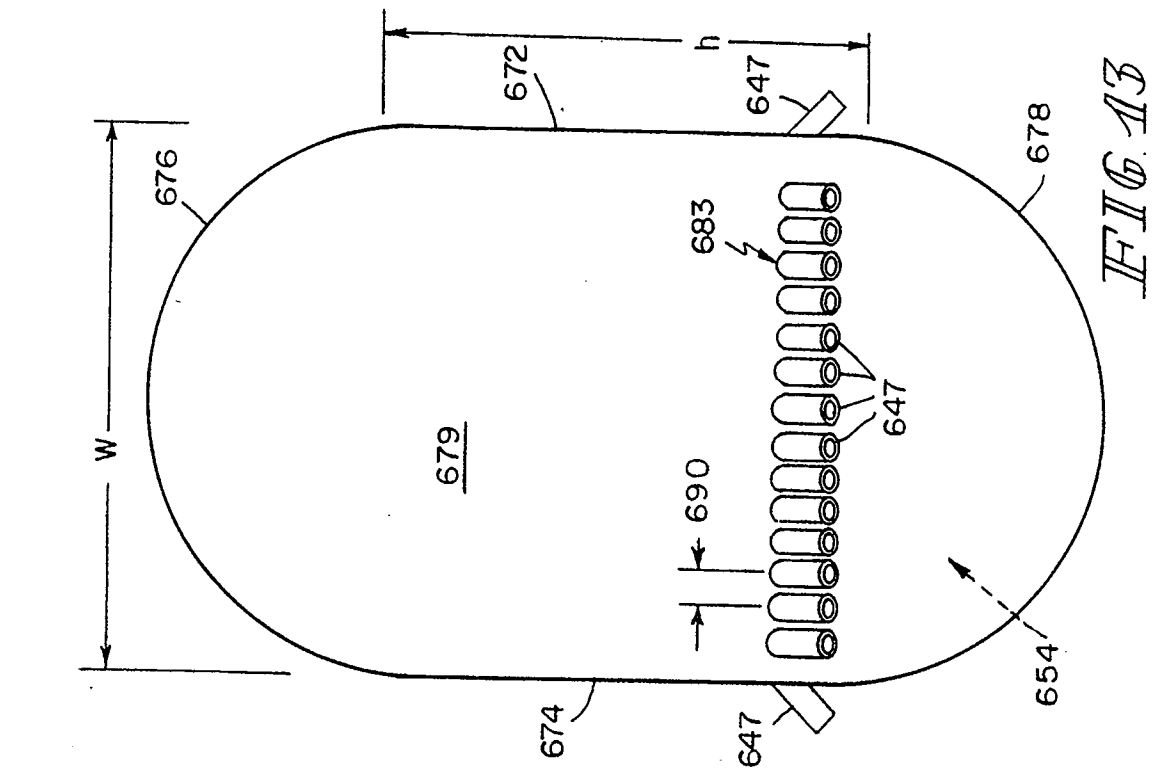


FIG. 13

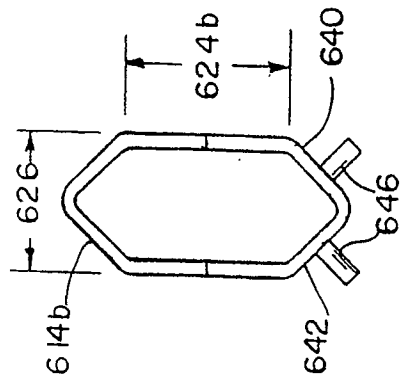


FIG. 14

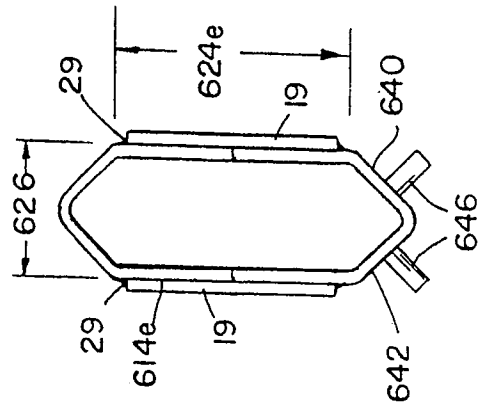


FIG. 16

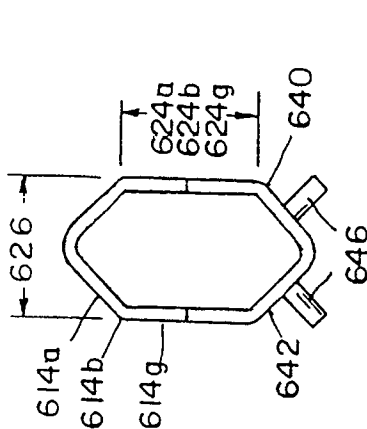


FIG. 17

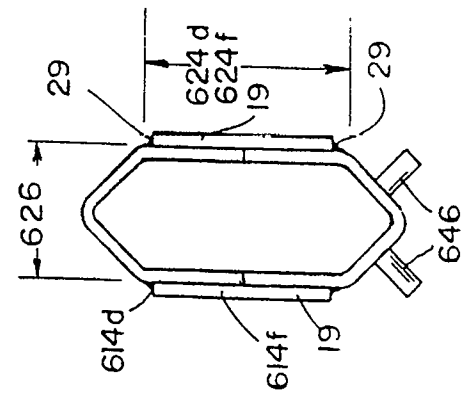
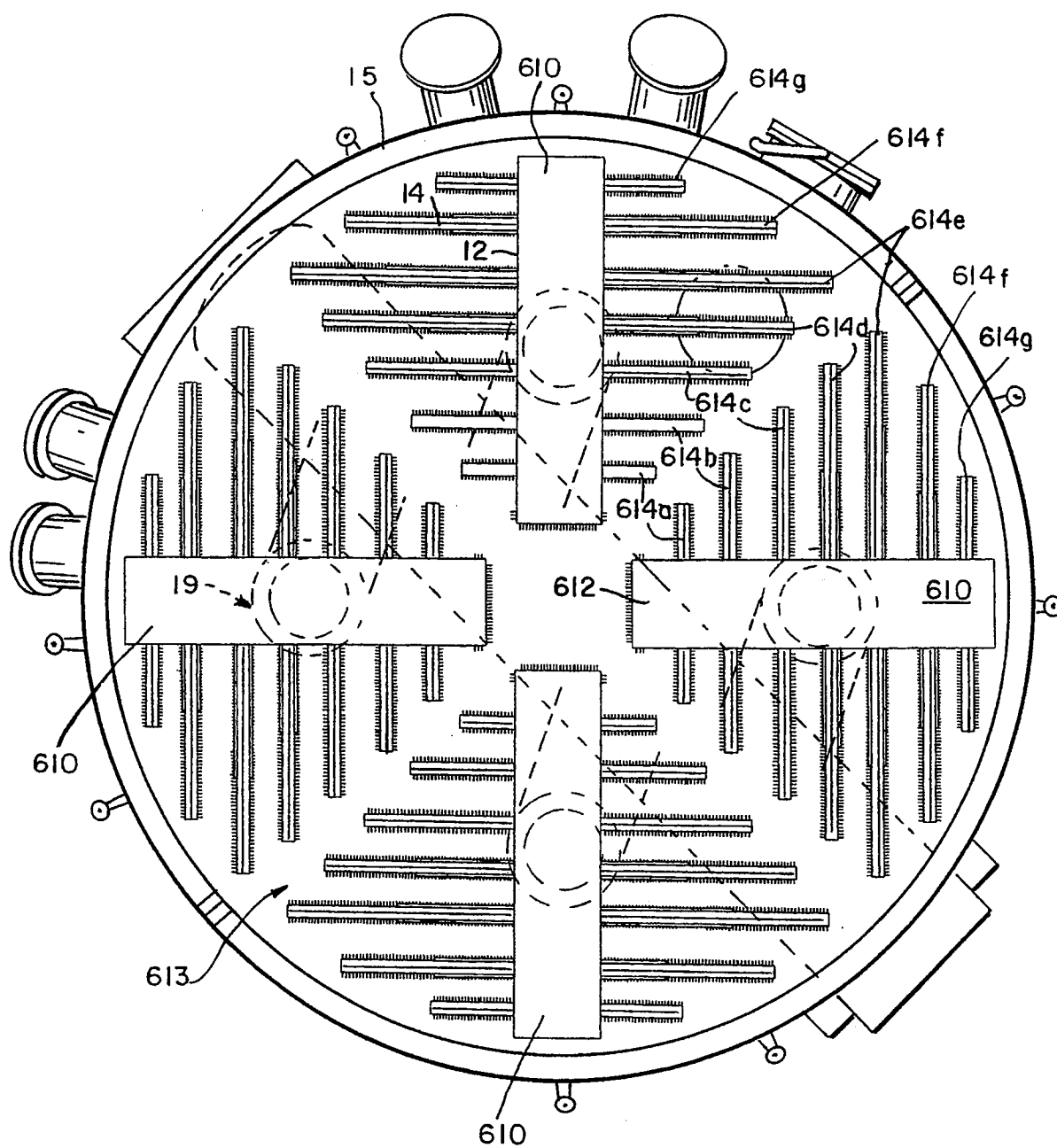


FIG. 18

*FIG. 18*

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/27204

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : B01J 8/18; B01D 47/16

US CL : 422/143; 261/97

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 422/143, 211, 194, 311; 261/97, 114.3, 114.5, 115, 126

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS distributor and grid and header or manifold

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,904,548 A (FAGAN ET AL.) 09 September 1975 (09-09-75), see entire document.	1-23
Y	US 3,419,251 A (ECKERT) 31 December 1968 (31-12-68), see entire document.	1-23
Y	US 3,360,246 A (ECKERT) 26 December 1967 (26-12-67), see entire document.	1-23
Y	US 5,132,055 A (ALLEAUME ET AL.) 21 July 1992 (21-07-92), see entire document.	1-23
Y,P	US 5,785,900 A (BELOT ET AL.) 28 July 1998 (28-07-98), see entire document.	1-23

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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*E* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

23 MARCH 1999

Date of mailing of the international search report

08 APR 1999

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